BlueFors CRYOGENICS

BF-LD250

CRYOGEN-FREE

DILUTION REFRIGERATOR SYSTEM

Serial no: BF0317-04

PERFORMANCE SHEET

and

CALIBRATION REPORT

March 16, 2017

1. Factory Performance Test

Base temperature: **6.0 mK**

Conditions:

n = 0.450 mmol/s (P_{still} = 5 mW)

p_{still} = 0.038 mbar

p_{con} = 455 mbar

Date measured: March 4, 2017

Cooling power at 20 mK: **15 μW**

Conditions:

n = 0.890 mmol/s (P_{still} = 25 mW)

p_{still} = 0.200 mbar

p_{con} = 520 mbar

Date measured: March 3, 2017

Cooling power at 100 mK: **445 μW**

Conditions:

n = 0.900 mmol/s (P_{still} = 25 mW)

p_{still} = 0.280 mbar

p_{con} = 540 mbar

Date measured: March 3, 2017

Operator: T. K.

Signature: _____

2. Thermometers and Heaters

Thermometers:

Location	Type	S.N.	Calibrated range [Kelvin]	Default channel res. bridge	LS-372 excitation level
50K-flange	PT100	pt1275	310 – 20	Channel 1	2 mV
4K-flange	Cernox CX-1010 (LakeShore)	x116777	310 – 0.1	Channel 2	632 μV
Still	Cernox CX-1010 (LakeShore)	x115419	310 – 0.1	Channel 5	200 μV
Mixing Chamber	RuO2. RX-102B (LakeShore) *filtered*	R10250	100 – 0.007	Channel 6	20 μV
Mixing Chamber	RuO2. RX-102B (LakeShore) *filtered*	R10287	not calibrated	Channel 8	20 μV

Heaters:

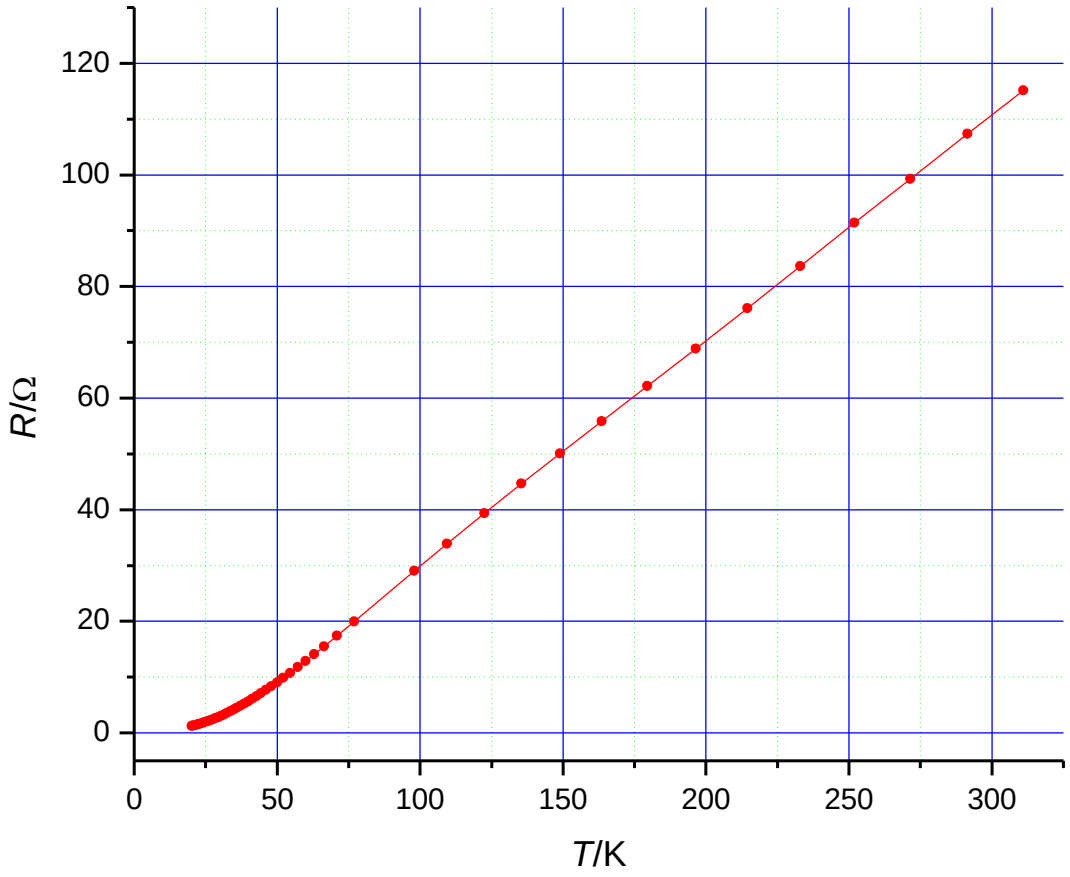
Location	Heater value at Low-T [Ohm]	Measured value at RT [Ohm]	Op. current [mA]	Default connection ch.
Heat Switch Still	120	~50 (4 heaters parallel)	60	Channel 1
Heat Switch MC	120	~90 (2 heaters parallel)	30	Channel 2
Still	120	~155	0 – 15 (0 – 27 mW)	Channel 3
Mixing Chamber	120	~170	N.A.	Channel 4

Heater box factory settings:

Channel	Current [mA]
1 (HS-STILL)	60
2 (HS-MC)	30
3 (Still heater)	10

3. Resistor Sensor Calibrations

pt1275 (ch 1)

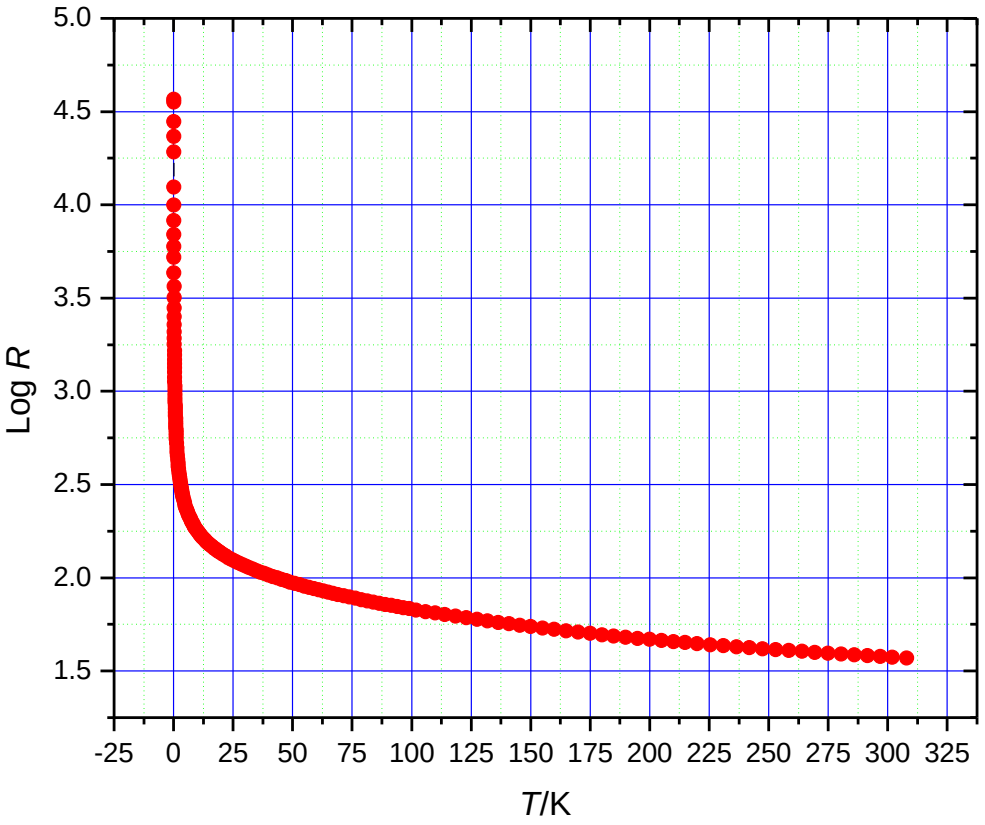


Sensor Model: PT-100-20K
Serial Number: Pt1275
Data Format: 3 (Ohms/Kelvin)
SetPoint Limit: 325.0 (Kelvin)
Temperature coefficient: 2 (Positive)
Number of Breakpoints: 49

No.	Units	Temperature (K)						
1	1.22481	20.1	8	2.05998	25.7	15	3.53751	32.5
2	1.30797	20.8	9	2.22834	26.6	16	3.81775	33.6
3	1.41074	21.6	10	2.40545	27.5	17	4.13527	34.8
4	1.52159	22.4	11	2.59106	28.4	18	4.46461	36
5	1.64031	23.2	12	2.80696	29.4	19	4.83417	37.3
6	1.76671	24	13	3.03273	30.4	20	5.21642	38.6
7	1.90061	24.8	14	3.26803	31.4	21	5.64158	40

22	6.08007	41.4	32	14.08082	63	42	62.13483	179.5
23	6.53119	42.8	33	15.52279	66.5	43	68.8792	196.5
24	7.06136	44.4	34	17.40945	71	44	76.10745	214.5
25	7.67528	46.2	35	19.96543	77	45	83.62569	233
26	8.30643	48	36	29.0229	98	46	91.38564	252
27	9.02639	50	37	33.92665	109.5	47	99.30583	271.5
28	9.83917	52.2	38	39.36044	122.5	48	107.3293	291.5
29	10.74835	54.6	39	44.67291	135.5	49	115.1333	311
30	11.75694	57.2	40	50.08469	149			
31	12.86727	60	41	55.82438	163.5			

x116777 (ch 2)

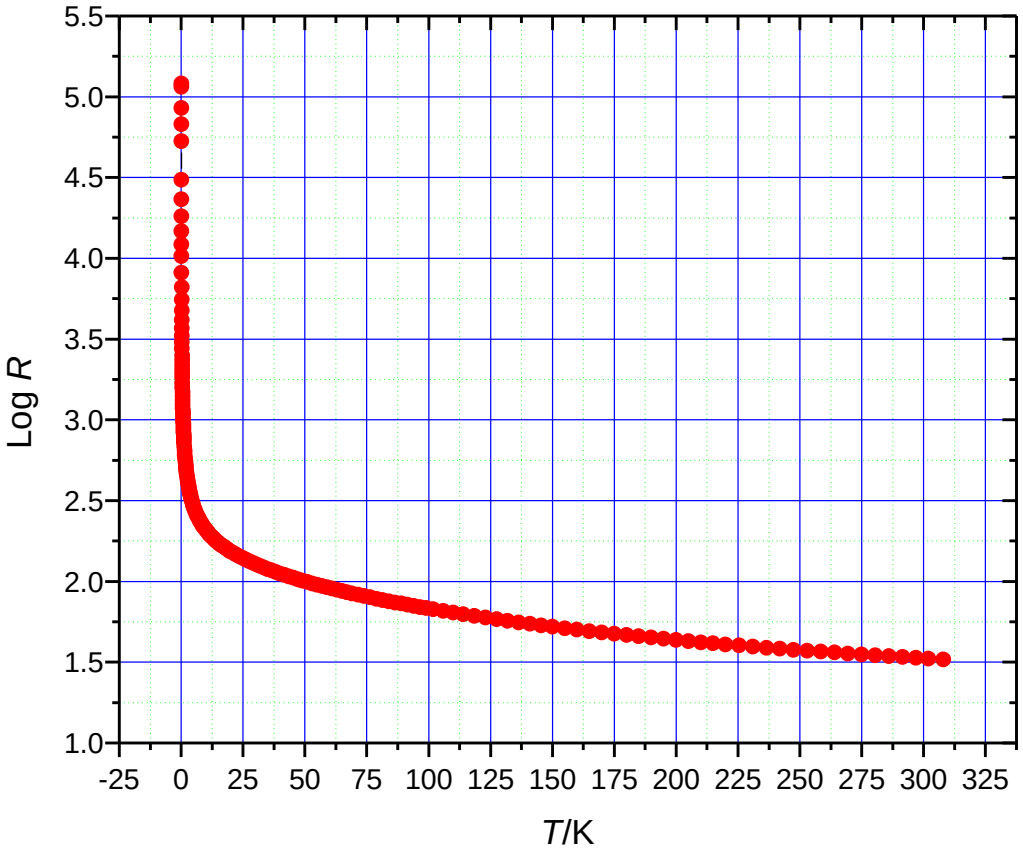


Sensor Model: CX-1010-CD-BF0.1
Serial Number: X116777
Data Format: 4 (Log Ohms/Kelvin)
SetPoint Limit: 325.0 (Kelvin)
Temperature coefficient: 1 (Negative)
Number of Breakpoints: 180

No.	Units	Temperature (K)						
1	1.56796	308	13	1.62418	242	25	1.69397	180
2	1.5726	302	14	1.62947	236.5	26	1.70071	175
3	1.57666	297	15	1.63492	231	27	1.70765	170
4	1.58119	291.5	16	1.64054	225.5	28	1.71478	165
5	1.58564	286	17	1.64632	220	29	1.72213	160
6	1.59039	280.5	18	1.65172	215	30	1.7297	155
7	1.59509	275	19	1.65727	210	31	1.7375	150
8	1.5999	269.5	20	1.66298	205	32	1.74473	145.5
9	1.60448	264	21	1.66884	200	33	1.75216	141
10	1.60919	258.5	22	1.67486	195	34	1.75981	136.5
11	1.61404	253	23	1.68106	190	35	1.76767	132
12	1.61904	247.5	24	1.68742	185	36	1.77578	127.5

37	1.78413	123	85	2.13948	19.1	133	2.67341	1.56
38	1.79273	118.5	86	2.14574	18.4	134	2.6952	1.45
39	1.80161	114	87	2.15225	17.7	135	2.71956	1.34
40	1.80975	110	88	2.15854	17.05	136	2.74421	1.24
41	1.81813	106	89	2.16509	16.4	137	2.76026	1.18
42	1.82676	102	90	2.17194	15.75	138	2.7766	1.135
43	1.83341	99	91	2.17853	15.15	139	2.79008	1.09
44	1.83907	96.5	92	2.18542	14.55	140	2.80441	1.045
45	1.84484	94	93	2.19264	13.95	141	2.8196	1
46	1.85074	91.5	94	2.19957	13.4	142	2.83393	0.96
47	1.85675	89	95	2.20683	12.85	143	2.85284	0.92
48	1.8629	86.5	96	2.21446	12.3	144	2.86898	0.88
49	1.86919	84	97	2.22174	11.8	145	2.88619	0.84
50	1.87561	81.5	98	2.22939	11.3	146	2.90463	0.8
51	1.88219	79	99	2.23745	10.8	147	2.9219	0.765
52	1.88892	76.5	100	2.24597	10.3	148	2.94036	0.73
53	1.89581	74	101	2.25406	9.85	149	2.96017	0.695
54	1.90289	71.5	102	2.26261	9.4	150	2.98152	0.66
55	1.91014	69	103	2.27168	8.95	151	3.00464	0.625
56	1.91609	67	104	2.28021	8.55	152	3.02608	0.595
57	1.92217	65	105	2.28924	8.15	153	3.04924	0.565
58	1.92839	63	106	2.29884	7.75	154	3.07437	0.535
59	1.93476	61	107	2.30906	7.35	155	3.1018	0.505
60	1.94128	59	108	2.32	6.95	156	3.12463	0.482
61	1.94798	57	109	2.33023	6.6	157	3.14593	0.462
62	1.95485	55	110	2.34117	6.25	158	3.16876	0.442
63	1.96191	53	111	2.35359	5.88	159	3.19331	0.422
64	1.96917	51	112	2.3659	5.54	160	3.21708	0.404
65	1.97665	49	113	2.37473	5.22	161	3.25162	0.38
66	1.98359	47.2	114	2.38734	4.92	162	3.28327	0.36
67	1.99074	45.4	115	2.40082	4.62	163	3.31798	0.34
68	1.99811	43.6	116	2.41572	4.32	164	3.3563	0.32
69	2.00572	41.8	117	2.43063	4.04	165	3.39891	0.3
70	2.01405	39.9	118	2.44295	3.83	166	3.44666	0.28
71	2.02177	38.2	119	2.45385	3.65	167	3.50066	0.26
72	2.02978	36.5	120	2.46588	3.47	168	3.56241	0.24
73	2.03761	34.9	121	2.4785	3.29	169	3.63388	0.22
74	2.04574	33.3	122	2.49111	3.12	170	3.71783	0.2
75	2.05422	31.7	123	2.50487	2.95	171	3.77577	0.188
76	2.06251	30.2	124	2.51891	2.79	172	3.84073	0.176
77	2.07118	28.7	125	2.53353	2.63	173	3.91417	0.164
78	2.08026	27.2	126	2.54872	2.48	174	3.99799	0.152
79	2.08916	25.8	127	2.56506	2.33	175	4.09474	0.14
80	2.09784	24.5	128	2.5814	2.19	176	4.28321	0.121
81	2.10697	23.2	129	2.59545	2.05	177	4.36698	0.114
82	2.11661	21.9	130	2.6135	1.92	178	4.44665	0.108
83	2.12603	20.7	131	2.63328	1.79	179	4.5505	0.101
84	2.13346	19.8	132	2.65335	1.67	180	4.56642	0.1

x115419 (ch 5)

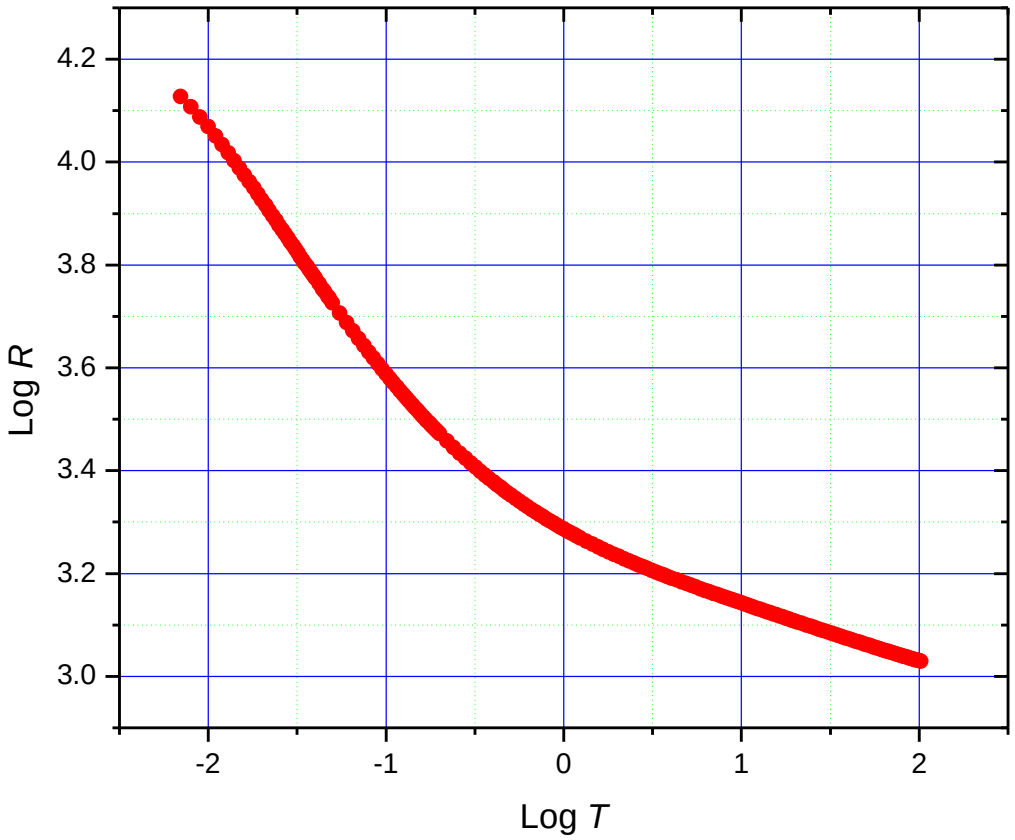


Sensor Model: CX-1010-CD-BF0.1
Serial Number: X115419
Data Format: 4 (Log Ohms/Kelvin)
SetPoint Limit: 325.0 (Kelvin)
Temperature coefficient: 1 (Negative)
Number of Breakpoints: 180

No.	Units	Temperature (K)						
1	1.51582	308	13	1.58277	242	25	1.66685	180
2	1.5212	302	14	1.58916	236.5	26	1.67494	175
3	1.52606	297	15	1.59575	231	27	1.68327	170
4	1.53127	291.5	16	1.60252	225.5	28	1.69184	165
5	1.53663	286	17	1.60949	220	29	1.70066	160
6	1.54212	280.5	18	1.61601	215	30	1.70974	155
7	1.54776	275	19	1.6227	210	31	1.71909	150
8	1.55336	269.5	20	1.62957	205	32	1.72776	145.5
9	1.55891	264	21	1.63662	200	33	1.73667	141
10	1.56462	258.5	22	1.64387	195	34	1.74583	136.5
11	1.5705	253	23	1.65132	190	35	1.75526	132
12	1.57655	247.5	24	1.65898	185	36	1.76497	127.5

37	1.77497	123	85	2.1947	19.1	133	2.78104	1.56
38	1.78527	118.5	86	2.20181	18.4	134	2.80502	1.45
39	1.79591	114	87	2.2092	17.7	135	2.83167	1.34
40	1.80565	110	88	2.21632	17.05	136	2.8587	1.24
41	1.81567	106	89	2.22373	16.4	137	2.87646	1.18
42	1.826	102	90	2.23144	15.75	138	2.89065	1.135
43	1.83396	99	91	2.23885	15.15	139	2.90567	1.09
44	1.84073	96.5	92	2.24658	14.55	140	2.92162	1.045
45	1.84764	94	93	2.25465	13.95	141	2.9386	1
46	1.85469	91.5	94	2.26238	13.4	142	2.95467	0.96
47	1.86188	89	95	2.27046	12.85	143	2.97177	0.92
48	1.86923	86.5	96	2.27893	12.3	144	2.99001	0.88
49	1.87674	84	97	2.28699	11.8	145	3.00954	0.84
50	1.88442	81.5	98	2.29545	11.3	146	3.03054	0.8
51	1.89228	79	99	2.30433	10.8	147	3.05027	0.765
52	1.90032	76.5	100	2.31369	10.3	148	3.07145	0.73
53	1.90856	74	101	2.32257	9.85	149	3.09427	0.695
54	1.917	71.5	102	2.33193	9.4	150	3.11896	0.66
55	1.92566	69	103	2.34182	8.95	151	3.14581	0.625
56	1.93276	67	104	2.35111	8.55	152	3.17081	0.595
57	1.94001	65	105	2.36093	8.15	153	3.19793	0.565
58	1.94742	63	106	2.37133	7.75	154	3.22749	0.535
59	1.95501	61	107	2.3824	7.35	155	3.25989	0.505
60	1.96278	59	108	2.39421	6.95	156	3.28696	0.482
61	1.97074	57	109	2.40524	6.6	157	3.31231	0.462
62	1.97892	55	110	2.417	6.25	158	3.33957	0.442
63	1.98731	53	111	2.43034	5.88	159	3.36898	0.422
64	1.99594	51	112	2.44353	5.54	160	3.39754	0.404
65	2.00482	49	113	2.4569	5.22	161	3.43919	0.38
66	2.01305	47.2	114	2.47038	4.92	162	3.47751	0.36
67	2.02151	45.4	115	2.48493	4.62	163	3.51969	0.34
68	2.03023	43.6	116	2.50071	4.32	164	3.56642	0.32
69	2.03923	41.8	117	2.51673	4.04	165	3.61856	0.3
70	2.04906	39.9	118	2.52969	3.83	166	3.67721	0.28
71	2.05816	38.2	119	2.54153	3.65	167	3.74379	0.26
72	2.06759	36.5	120	2.55414	3.47	168	3.82019	0.24
73	2.07679	34.9	121	2.56761	3.29	169	3.90893	0.22
74	2.08633	33.3	122	2.58123	3.12	170	4.01355	0.2
75	2.09625	31.7	123	2.59584	2.95	171	4.08594	0.188
76	2.10594	30.2	124	2.61061	2.79	172	4.16725	0.176
77	2.11603	28.7	125	2.62652	2.63	173	4.25934	0.164
78	2.12659	27.2	126	2.64262	2.48	174	4.36464	0.152
79	2.13691	25.8	127	2.66004	2.33	175	4.48636	0.14
80	2.14695	24.5	128	2.67769	2.19	176	4.7239	0.121
81	2.15748	23.2	129	2.69689	2.05	177	4.82962	0.114
82	2.16856	21.9	130	2.71636	1.92	178	4.93021	0.108
83	2.17935	20.7	131	2.73767	1.79	179	5.06137	0.101
84	2.18784	19.8	132	2.75928	1.67	180	5.08148	0.1

R10250 (ch 6)



Sensor Model: RU-1000-BF0.007
Serial Number: R10250
Data Format: 4 (Log Ohms/Kelvin)
SetPoint Limit: 100.0 (Kelvin)
Temperature coefficient: 1 (Negative)
Number of Breakpoints: 198

No.	Units	Temperature (K)						
1	3.02939	102	12	3.04378	74	23	3.06129	51
2	3.03069	99	13	3.04537	71.5	24	3.06321	49
3	3.03182	96.5	14	3.04701	69	25	3.06501	47.2
4	3.03298	94	15	3.04838	67	26	3.06689	45.4
5	3.03417	91.5	16	3.0498	65	27	3.06885	43.6
6	3.03541	89	17	3.05126	63	28	3.0709	41.8
7	3.03669	86.5	18	3.05278	61	29	3.07317	39.9
8	3.03801	84	19	3.05435	59	30	3.0753	38.2
9	3.03937	81.5	20	3.05598	57	31	3.07753	36.5
10	3.04079	79	21	3.05768	55	32	3.07974	34.9
11	3.04226	76.5	22	3.05945	53	33	3.08205	33.3

34	3.08448	31.7	83	3.21309	2.79	132	3.48389	0.185
35	3.08688	30.2	84	3.21675	2.63	133	3.48815	0.18
36	3.0894	28.7	85	3.22044	2.48	134	3.49257	0.175
37	3.09207	27.2	86	3.22443	2.33	135	3.49715	0.17
38	3.0947	25.8	87	3.22845	2.19	136	3.50192	0.165
39	3.09728	24.5	88	3.23282	2.05	137	3.50688	0.16
40	3.1	23.2	89	3.23724	1.92	138	3.51204	0.155
41	3.10289	21.9	90	3.24206	1.79	139	3.51743	0.15
42	3.10571	20.7	91	3.24693	1.67	140	3.52305	0.145
43	3.10794	19.8	92	3.25182	1.56	141	3.52893	0.14
44	3.10975	19.1	93	3.25719	1.45	142	3.53509	0.135
45	3.11163	18.4	94	3.26313	1.34	143	3.54155	0.13
46	3.11358	17.7	95	3.26912	1.24	144	3.54833	0.125
47	3.11547	17.05	96	3.27304	1.18	145	3.55547	0.12
48	3.11743	16.4	97	3.27616	1.135	146	3.563	0.115
49	3.11947	15.75	98	3.27945	1.09	147	3.57095	0.11
50	3.12144	15.15	99	3.28293	1.045	148	3.57937	0.105
51	3.12348	14.55	100	3.28661	1	149	3.58831	0.1
52	3.12562	13.95	101	3.29009	0.96	150	3.59783	0.095
53	3.12766	13.4	102	3.29376	0.92	151	3.60799	0.09
54	3.12979	12.85	103	3.29767	0.88	152	3.61887	0.085
55	3.13202	12.3	104	3.30182	0.84	153	3.63057	0.08
56	3.13413	11.8	105	3.30625	0.8	154	3.64319	0.075
57	3.13634	11.3	106	3.31038	0.765	155	3.65687	0.07
58	3.13866	10.8	107	3.31478	0.73	156	3.67177	0.065
59	3.14109	10.3	108	3.31949	0.695	157	3.68811	0.06
60	3.14339	9.85	109	3.32452	0.66	158	3.70612	0.055
61	3.1458	9.4	110	3.32994	0.625	159	3.72613	0.05
62	3.14834	8.95	111	3.33493	0.595	160	3.73479	0.048
63	3.15071	8.55	112	3.34028	0.565	161	3.73927	0.047
64	3.15321	8.15	113	3.34603	0.535	162	3.74857	0.045
65	3.15584	7.75	114	3.35224	0.505	163	3.7534	0.044
66	3.15862	7.35	115	3.35736	0.482	164	3.76342	0.042
67	3.16157	6.95	116	3.36209	0.462	165	3.774	0.04
68	3.16431	6.6	117	3.36711	0.442	166	3.7795	0.039
69	3.16721	6.25	118	3.37245	0.422	167	3.78516	0.038
70	3.17048	5.88	119	3.37756	0.404	168	3.79099	0.037
71	3.1737	5.54	120	3.38488	0.38	169	3.79699	0.036
72	3.17694	5.22	121	3.39148	0.36	170	3.80317	0.035
73	3.18019	4.92	122	3.3986	0.34	171	3.80954	0.034
74	3.18367	4.62	123	3.40631	0.32	172	3.81612	0.033
75	3.18743	4.32	124	3.41471	0.3	173	3.8229	0.032
76	3.19122	4.04	125	3.4239	0.28	174	3.82992	0.031
77	3.19427	3.83	126	3.43402	0.26	175	3.83717	0.03
78	3.19705	3.65	127	3.44525	0.24	176	3.84468	0.029
79	3.2	3.47	128	3.4578	0.22	177	3.85245	0.028
80	3.20314	3.29	129	3.47197	0.2	178	3.86051	0.027
81	3.2063	3.12	130	3.47581	0.195	179	3.86888	0.026
82	3.20968	2.95	131	3.47978	0.19	180	3.87757	0.025

181	3.88661	0.024	187	3.94971	0.018	193	4.03409	0.012
182	3.89603	0.023	188	3.96203	0.017	194	4.05098	0.011
183	3.90584	0.022	189	3.97497	0.016	195	4.06882	0.01
184	3.91608	0.021	190	3.98859	0.015	196	4.0876	0.009
185	3.92678	0.02	191	4.00295	0.014	197	4.10726	0.008
186	3.93798	0.019	192	4.01809	0.013	198	4.12759	0.007